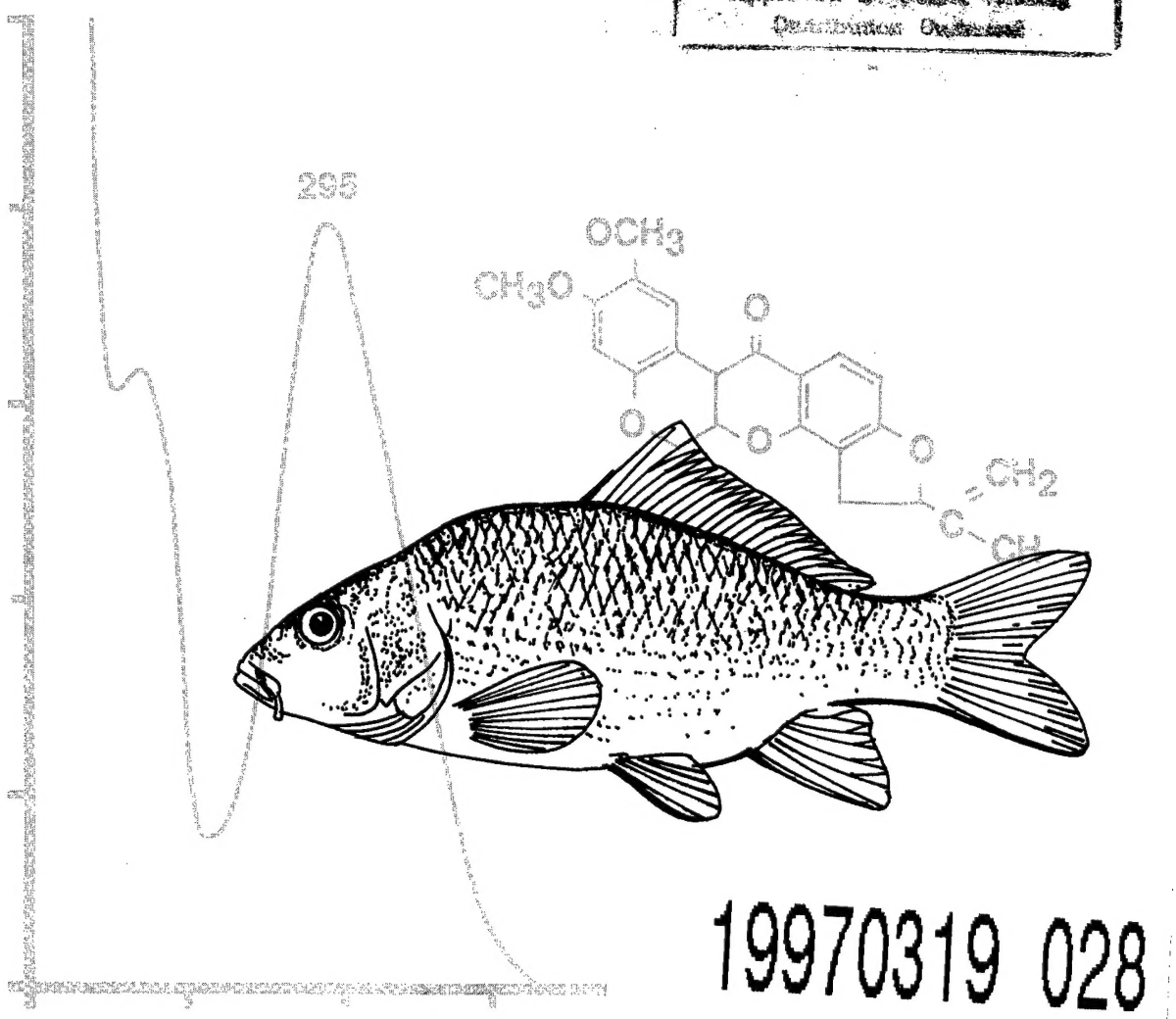
Evaluation of Five Anesthetics on Striped Bass



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By Carol A. Lemm

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Evaluation of Five Anesthetics on Striped Bass

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Abstract. Five anesthetics were tested on subadult striped bass (*Morone saxatilis*) in hard water at temperatures of 13°, 18°, and 23° C. The recommended concentrations of anesthetics for sedation (reduced reaction to external stimuli without loss of equilibrium) of 300–1,500-g striped bass are 40 mg/L MS-222, 25 mg/L benzocaine, 5 mg/L quinaldine, 5 mg/L quinaldine sulfate, and 0.5 mg/L metomidate. The lowest effective concentrations for immobilization (defined as anesthesia within 3 min and recovery within 10 min after a 15-min exposure) at 13°, 18°, and 23° C, respectively, for each anesthetic were 150, 150, and 150 mg/L for MS-222; 85–100, 70, and 55 mg/L for benzocaine; 40, 25, and 25 mg/L for quinaldine; 55, 25, and 25 mg/L for quinaldine sulfate; and 7.5, 10, and 10 mg/L for metomidate.

Key words: Anesthetic, *Morone saxatilis*, sedative, striped bass, toxicity.

Anesthetics are routinely used to sedate or immobilize fish during fish husbandry activities such as weighing, marking, transporting, and spawning. Various procedures require selection of an anesthetic to meet certain criteria, such as rapid induction and recovery, deep or light anesthesia, minimal physiological stress to the fish, or prolonged exposure time. Tests have been conducted, primarily with freshwater fish, to evaluate the efficacy of tricaine methanesulfonate (MS-222), 2-methylquinoline (quinaldine), 2-methylquinoline sulfate (quinaldine sulfate), ethyl-*p*-amino benzoate (benzocaine), 2-phenoxyethanol (2 PE), sodium bicarbonate, and *r*-(+) ethyl-*l*-(1-phenylethyl)-1*H* imidazole-5 carboxylate (etomidate) and its analog (+)-1-methylbenzyl-imidazole-5-carboxylate (metomidate). Each of these drugs has advantages and disadvantages for use with a particular fish species or rearing environment. Of these anesthetic agents, only MS-222 is registered by the Food and Drug Administration (FDA) for use on food fish in the United States, although efforts are under way to register benzocaine for use on food fish (Schnick 1988; Gilderhus 1990).

Limited information is available on anesthetics for striped bass, *Morone saxatilis* (Tatum et al. 1966; Luhning 1973; Davis et al. 1982; Plumb et al. 1983; Bills et al. 1990), and those studies used fish of less than 100 g. Except for recent work with benzocaine (Gilderhus et al. 1991), information is lacking on the potency, safety, and effectiveness of anesthetics for larger striped bass. The objective of this study was to evaluate various anesthetics for subadult striped bass and to determine effective doses for sedation and immobilization of the fish at 13°, 18°, and 23° C. We tested five anesthetics on striped bass ranging from 300 to 1,500 g during January 1989–December 1990 at the U.S. Fish and Wildlife Service Fish Culture Laboratory, Kearneysville, West Virginia.

Methods

Fish

Subadult Chesapeake Bay striped bass (between 300 and 1,500 g and 25–49 cm total length) were held in concrete raceways (8.5 × 1.0 × 0.8 m) or circular 3,800-L fiberglass tanks (2.4 m in diameter) at 12.5–13.0° C and fed the U.S. Fish and Wildlife Service open-formula Atlantic salmon diet. When fish were needed for testing at 18° or 23° C, the temperature was raised over a period of 3–4 days, and the fish were held at the test temperature for a minimum of 14 days before being used in the individual tests. The tests were conducted in hard spring water (pH, 7.0–7.8; total alkalinity, 292 mg/L; total calcium carbonate hardness, 342 mg/L). Fish were not fed for 24 h before testing.

Testing Protocol

The criterion for the recommended working application (effective concentration) was the lowest concentration that resulted in anesthesia of the fish within a 3-min period and recovery within 10 min following a 15-min exposure. The sedation concentration was that level resulting in reduced reaction of fish to external stimuli but without general loss of equilibrium (i.e., the fish appeared quiet and remained upright without response to a hand passed near and around the head).

Drugs were mixed on the day of use, and an appropriate aliquot for the test concentration was added to a circular tank containing 40 L of water at the selected test temperature. A fish was removed from the holding tank with a soft mesh net and placed in the prepared exposure medium. Anesthesia induction time was measured from the moment of contact with the anesthetic until the fish reached approximately Stage II—Plane 2 as described by McFarland (1960). At this point, fish could be handled easily, and total length (mm) and weight (g) were determined for each fish. Each fish was returned to the exposure water for the 15-min duration. During each test, water temperature was maintained at the selected temperature (±1° C), and oxygen was maintained at 5 mg/L or higher. The pH of the test water was determined for each drug concentration.

Following the exposure period, fish were transferred to drug-free water of the same temperature as the exposure water. Recovery time was the interval required for the fish to regain equilibrium and normal swimming ability. Following exposure, the fish were returned to a separate partitioned rearing unit and observed for 48 h.

Five fish were exposed at each concentration of the drug, beginning at low concentrations and progressing generally by 15-mg/L increments (except for metomidate, where increments were 2.5 mg/L) until fish had been evaluated at a concentration at least two increments above the effective concentration. Individuals were not used more than once during testing. After two fish had been exposed, the anesthetic and recovery solutions were replaced with fresh media.

The relations between concentration, temperature, and the time required for anesthesia and recovery were determined by correlation analysis (Pearson product moment correlation; Sokal and Rohlf 1981).

Anesthetics and Their Preparation

MS-222 and Benzocaine

Benzocaine and MS-222 (both derivatives of *p*-amino benzoic acid) act to depress the respiratory centers and have been known to result in mortality of fish due to anoxia. Benzocaine has been used in veterinary and human medicine (Dawson and Gilderhus 1979), and MS-222 has achieved wide acceptance as a fish anesthetic and as a sedative in transportation (Schoettger and Julin 1966).

Tricaine methanesulfonate (Crescent Research Chemicals, Phoenix, Arizona) is a white crystalline powder, which we dissolved in water to a stock solution of 100 mg/mL. Benzocaine (Sigma Chemicals, St. Louis, Missouri) is not water soluble and was dissolved in 95% ethyl alcohol for a stock solution of 33 mg/mL.

Because of its acidic nature, MS-222 can reduce the pH of fresh water (Smit et al. 1977), which can be stressful to the fish (Wedemeyer 1970; Smit et al. 1977). Neutralization of the anesthetic solution is recommended to reduce stressful side effects of a pH shift (Smit et al. 1978). However, this was

not necessary in our study because of the high buffering capacity of the test water; the highest concentrations of MS-222 resulted in less than a 0.5-unit decrease in pH of the test solution.

Quinaldine and Quinaldine Sulfate

Quinaldine (Crescent Research Chemicals) is an oily liquid with a strong acrid odor and is not readily soluble in water. We mixed quinaldine with an equal volume of acetone before dilution with deionized water to the working concentration of 40 mg/mL. Quinaldine sulfate (Crescent Research Chemicals) is a sulfate salt of quinaldine, which we dissolved with 10% sodium bicarbonate and deionized water to produce a 50-mg/mL solution with pH 6.5–7.2 (active quinaldine about 28.6 mg/mL). Tests on quinaldine sulfate were conducted at equivalent active quinaldine concentrations. Quinaldine and quinaldine sulfate have a barbiturate-like action, involving depression of the central nervous system and respiratory system (Bell 1967). Although not approved for general use with fish, these drugs have been found useful in research for anesthetizing various species of fish (Schoettger and Julin 1969; Gilderhus et al. 1973; Blasiola 1977).

Metomidate

Metomidate is a short-acting, water soluble, nonbarbiturate, hypnotic drug recently tested for use on a variety of marine and freshwater fish (Gilderhus and Marking 1987; Vermeer and Falls 1988; Mattson and Riple 1989). This experimental drug, obtained by prescription from a veterinarian, was dissolved in water (10 mg/mL) for testing.

Refer to Bell (1967) and Bell (1987) for general properties of the anesthetics, to McFarland (1959) for the physiological and behavioral aspects, and to Ross and Ross (1984) for various techniques of anesthesia.

Results and Discussion

All of the anesthetics tested were acceptable for use with striped bass. No fish died during the 15-min exposures at the test concentrations or within the 48-h monitoring period after exposure. Fish generally returned to normal feeding within the observation period.

Sedation

The concentration of each anesthetic recommended for sedation of subadult striped bass is the same for all three water temperatures (Table 1). These concentrations resulted in a marked reduction in reaction to external stimuli without a loss of equilibrium. The fish recovered to a normal swimming state shortly after transfer to anesthetic-free water. These concentrations can be used when decreased physical activity of fish is necessary, such as in transportation.

Anesthesia

Tables 2–6 show the effects of different concentrations of the drugs at the three test temperatures, the time required to induce anesthesia, and the subsequent time to recovery. The recommended working application is highlighted when the previously described test criteria were met (first anesthesia of the fish within a 3-min period and recovery within 10 min following a 15-min exposure). These data are considered valid for striped bass in hard water (>200 mg/L total hardness) when the exposure time is 15 min or less. Culturists who want to use these concentrations for longer exposures, with smaller fish, or in water of differing hardness should conduct a preliminary test at this concentration to ensure safe handling and recovery of the fish.

Correlation analyses for the relations between anesthetic concentration, temperature, and response times produced the following data. Induc-

Table 1. *Recommended concentrations of anesthetic required to sedate 300–1,500-g striped bass in hard water (200–350 mg/L as calcium carbonate).*

Anesthetic	Concentration[a] (mg/L)
MS-222	40
Benzocaine	25
Quinaldine	5
Quinaldine sulfate	5
Metomidate	0.5

[a] Concentration that results in a reduced reaction to external stimuli but without loss of equilibrium.

tion time generally decreased with increasing concentration of all drugs (MS-222, $r = -0.83$; benzocaine, $r = -0.75$; quinaldine, $r = -0.76$; quinaldine sulfate, $r = -0.65$; metomidate, $r = -0.81$). Temperature did not significantly affect induction time except for quinaldine ($r = -0.30$) and quinaldine sulfate ($r = -0.65$). Recovery time for each drug was reduced as test temperature increased (MS-222, $r = -0.41$; benzocaine, $r = -0.52$; quinaldine, $r = -0.25$, quinaldine sulfate, $r = -0.51$; metomidate, $r = -0.27$). Higher drug concentrations increased the recovery time in all instances except for MS-222, where recovery time was primarily affected by temperature (benzocaine, $r = 0.62$; quinaldine, $r = 0.78$; quinaldine sulfate, $r = 0.69$; metomidate, $r = 0.57$).

MS-222

Increasing the dosage of MS-222 decreased the time required to produce anesthesia ($r = -0.83$); induction time was not significantly correlated with water temperature. Recovery time was longer for each concentration at 13° and 23° C than for the same concentration at 18° C (Table 2). Striped bass survived concentrations of as high as 300 mg/L for the 15-min exposure test; however, recovery time of the fish tested at 13° C was as

Table 2. *Effects of MS-222 concentration and water temperature on time to anesthesia and recovery of striped bass* (n = 5). Shaded area *defines the recommended concentration for each water temperature. Criteria: anesthesia within about 3 min and recovery within 10 min following a 15-min exposure.*

Water temperature (° C)	Concentration (mg/L)	Induction time (min) to anesthesia ($\bar{x}$ ± SD)	Recovery time (min) to normal swimming ($\bar{x}$ ± SD)
13	40	8.81 ± 1.99 [a]	14.44 ± 3.78
	55	6.55 ± 2.45	11.68 ± 2.04
	70	4.60 ± 0.71	12.15 ± 0.90
	85	3.71 ± 0.36	12.52 ± 0.99
	100	3.16 ± 0.23	12.54 ± 2.78
	150	2.70 ± 0.31	9.69 ± 3.35
	200	2.62 ± 0.23	9.99 ± 1.23
	300	1.78 ± 0.09	22.46 ±10.97
18	40	[b]	4.17 ± 0.61
	55	10.50[c]	6.13 ± 1.06
	70	6.43 ± 1.33	8.37 ± 1.76
	85	5.13 ± 0.83	8.85 ± 1.51
	100	3.50 ± 0.33	4.28 ± 0.53
	150	2.45 ± 0.43	4.21 ± 0.87
	200	1.86 ± 19	5.79 ± 1.37
	300	1.84 ± 0.18	8.23 ± 3.03
23	40	[b]	8.61 ± 1.24
	55	12.06 ± 1.37	7.48 ± 0.42
	70	7.37 ± 1.26	8.19 ± 1.28
	85	4.02 ± 0.39	8.66 ± 1.37
	100	3.11 ± 0.38	4.41 ± 0.53
	150	2.06 ± 0.24	5.95 ± 1.45
	200	1.83 ± 0.10	11.78 ± 3.94
	300	1.15 ± 0.15	9.18 ± 3.24

[a] Two of five fish anesthetized in 15 min.
[b] Fish were not anesthetized in 15 min.
[c] One of five fish anesthetized in 15 min.

long as 41.5 min (mean 22.46 ± 10.97 min). Although the recommended concentration for all temperatures is 150 mg/L, a concentration of 100 mg/L is equally acceptable and, for safety reasons, may be preferable when handling fish at 23° C. Striped bass in this study recovered from MS-222 exposures in a violent manner, particularly at 13° C. Recovery was characterized by violent and erratic swimming, impacting the sides of the tank, and "tail walking." In tail walking the fish, oriented vertically, moved around the tank with the head and upper body bobbing out of the water. These behaviors seem stressful to the fish and support some observations about MS-222 producing hyperactivity in spawning striped bass (B. Florence, Maryland Department of Natural Resources, personal communication). A current FDA regulation (Schnick et al. 1989), which requires that fish treated with MS-222 be held for 21 days before being consumed as food, is a substantial limitation for regular use of the drug in aquaculture and in situations where wild fish are captured, anesthetized for spawning, and immediately returned to the natural environment.

Benzocaine

A benzocaine concentration of 100 mg/L resulted in anesthesia within 3 min at 13° C. However, recovery times for all concentrations exceeded 10 min at this temperature (Table 3). A concentration of 70 mg/L met the test criteria at 18° C, and 55 mg/L at 23° C. This inverse relation between temperature and concentration required for anesthesia was also observed by Gilderhus et al. (1991) with striped bass. Recovery times of fish after exposure to benzocaine increased with increasing

Table 3. *Effects of benzocaine concentration and water temperature on time to anesthesia and recovery of striped bass* (n = 5). Shaded area *defines the recommended concentration for that water temperature. Criteria: anesthesia within or close to 3 min and recovery within 10 min following a 15-min exposure.*

Water temperature (° C)	Concentration (mg/L)	Induction time (min) to anesthesia ($\bar{x}$ ± SD)	Recovery time (min) to normal swimming ($\bar{x}$ ± SD)
13	25	[a]	[a]
	40	10.80 [b]	13.27 ± 3.98
	55	4.60 ± 0.69	11.71 ± 1.19
	70	3.41 ± 0.32	14.62 ± 2.84
	85	3.37 ± 0.54	22.04 ± 5.62
	100	2.25 ± 0.10	16.71 ± 3.79
	150	2.18 ± 0.33	24.72 ± 6.73
18	25	[c]	5.41 ± 0.50
	40	5.55 ± 0.34	6.43 ± 0.72
	55	3.51 ± 0.38	6.00 ± 3.01
	70	2.29 ± 0.27	6.41 ± 1.52
	85	2.35 ± 0.20	10.61 ± 1.66
	100	2.16 ± 0.27	10.47 ± 2.24
23	25	11.49 ± 0.37	7.18 ± 1.27
	40	5.76 ± 0.54	8.03 ± 1.59
	55	2.52 ± 0.15	8.07 ± 2.59
	70	2.11 ± 0.06	9.17 ± 1.22
	85	2.09 ± 0.25	8.67 ± 1.41
	100	1.50 ± 0.15	13.64 ± 4.67

[a] Test not performed at this concentration.
[b] One of five fish anesthetized in 15 min.
[c] Fish were not anesthetized in 15 min.

concentration (r = −0.62) and decreased with increasing temperature (r = −0.52). No fish died at any of the test concentrations during 15-min exposures. Previous work (Gilderhus et al. 1991) indicated that striped bass of 100 to 400 g could tolerate maximum concentrations of 110–130 mg/L benzocaine and were able to survive for up to 45 min in a concentration of 55 mg/L at 22° C and for 60 min in a concentration of 65 mg/L at 13° C.

Behavior of a fish during recovery from anesthesia with benzocaine differed from the recovery of fish from MS-222. After righting itself, the fish swam calmly around the recovery tank with its nose just out of the water and body at a 45° angle. The fish resumed a normal swimming posture without evidence of hyperactivity. In general, the fish appeared to be less stressed during the recovery period. Laird and Oswald (1975) also found benzocaine to be less of an excitant than unbuffered MS-222.

Benzocaine is effective on striped bass at lower concentrations than MS-222 (e.g., at 18° C, the effective concentration was 70 mg/L for benzocaine vs. 150 mg/L for MS-222), is less expensive (benzocaine = $0.07/g; MS-222 = $0.23/g), does not depress pH when the ethyl ester form is used, and seems to be less stressful to the fish during anesthesia and recovery. Benzocaine is already approved for use in humans and is, therefore, a reasonable drug candidate for use with fish. After registration by the FDA, benzocaine could replace MS-222 for routine fish anesthesia.

Quinaldine and Quinaldine Sulfate

Quinaldine and quinaldine sulfate, when compared at equivalent concentrations of quinaldine,

Table 4. *Effects of quinaldine concentration and water temperature on time to anesthesia and recovery of striped bass* (n = 5). Shaded area *defines the recommended concentration for that water temperature. Criteria: anesthesia within or close to 3 min and recovery within 10 min following a 15-min exposure.*

Water temperature (° C)	Concentration (mg/L)	Induction time (min) to anesthesia ($\bar{x}$ ± SD)	Recovery time (min) to normal swimming ($\bar{x}$ ± SD)
13	5	[a]	2.55 ± 0.28
	10	4.03 ± 1.18	3.89 ± 0.46
	25	3.03 ± 0.57	6.12 ± 0.89
	40	2.56 ± 0.25	8.88 ± 1.53
	55	2.27 ± 0.25	8.15 ± 0.66
	70	1.98 ± 0.19	16.49 ± 4.92
	110	1.27 ± 0.07	17.60 ± 2.42
18	5	[a]	1.89 ± 0.40
	10	4.25 ± 1.16	2.99 ± 0.31
	25	2.78 ± 0.36	5.09 ± 0.86
	40	2.79 ± 0.42	4.41 ± 0.39
	55	2.07 ± 0.51	7.42 ± 2.00
	70	1.74 ± 0.26	8.59 ± 1.37
	110	1.37 ± 0.18	10.16 ± 0.69
23	5	[a]	2.88 ± 0.38
	10	5.02 ± 1.30	3.17 ± 1.01
	25	1.89 ± 0.09	5.15 ± 0.53
	40	1.60 ± 0.27	5.85 ± 0.85
	55	1.16 ± 0.13	9.16 ± 0.68
	70	1.06 ± 0.06	9.75 ± 3.81
	110	1.12 ± 0.26	9.31 ± 1.40

[a] Fish were not anesthetized in 15 min.

Table 5. *Effects of quinaldine sulfate concentration and water temperature on time to anesthesia and recovery of striped bass* (n = 5). Shaded area *defines the recommended concentration for that water temperature. Criteria: anesthesia within or close to 3 min and recovery within 10 min following a 15-min exposure.*

Water temperature (° C)	Concentration (mg/L)	Induction time (min) to anesthesia ($\bar{x}$ ± SD)	Recovery time (min) to normal swimming ($\bar{x}$ ± SD)
13	5	[a]	2.56 ± 0.54
	10	6.32 ± 0.88	3.45 ± 0.48
	25	4.01 ± 0.84	8.52 ± 1.18
	40	3.48 ± 0.38	9.64 ± 2.68
	55	2.59 ± 0.39	11.74 ± 1.27
	70	1.78 ± 0.27	16.98 ± 2.34
	110	1.97 ± 0.09	21.02 ± 2.03
18	5	[a]	2.83 ± 0.77
	10	3.76 ± 0.65	3.55 ± 0.78
	25	2.77 ± 0.46	5.44 ± 0.83
	40	2.10 ± 0.32	5.86 ± 0.81
	55	1.68 ± 0.30	7.74 ± 1.08
	70	2.00 ± 0.28	10.59 ± 1.60
	110	1.49 ± 0.14	11.62 ± 1.41
23	5	[a]	2.29 ± 0.41
	10	[a]	2.07 ± 0.23
	25	2.24 ± 0.35	3.76 ± 0.66
	40	1.31 ± 0.18	3.62 ± 0.55
	55	1.31 ± 0.21	4.53 ± 0.17
	70	1.15 ± 0.08	6.86 ± 0.43
	110	1.18 ± 0.10	7.95 ± 1.21

[a] Fish were not anesthetized in 15 min.

produce essentially the same results (Tables 4 and 5). A higher concentration was required to produce anesthesia at 13° C (40–55 mg/L) than at 18° or 23° C (25 mg/L for both drugs). Fish subjected to quinaldine or quinaldine sulfate immediately responded to the chemical irritation of the drug at the gills. After the first indication of sedation, fish progressed rapidly to a total loss of equilibrium. As discussed by others (Meunch 1958; Locke 1969; Schoettger and Julin 1969), the quinaldine drugs fail to completely block the reflex response of the fish (strong stimuli can result in a jerking movement of the fish). However, at the recommended concentrations, striped bass could be easily handled for such processes as weighing, measuring, and tagging, although problems might occur at these concentrations if surgical procedures required total immobility.

One of the benefits of using these drugs is the rapid induction and recovery of the fish without hyperactivity during either stage. During recovery, the fish first remains immobile, but after righting itself, the fish swims off quickly without any lingering evidence of the effects of the anesthesia. This rapid recovery could be important, for example, when fish are anesthetized before being released into the natural environment. Of the two products, quinaldine sulfate is preferable because it does not irritate human mucous membranes. Quinaldine seems to lose its effectiveness as pH decreases and is totally ineffective at pH levels less than or equal to 5 (Schoettger and Julin 1969).

Metomidate

Rapid anesthesia of striped bass was obtained with metomidate at 7.5 mg/L and above. Fish succumbed quickly to the drug with no hyperactivity and little struggling. However, recovery time was generally increased. Although all fish survived and regained equilibrium and swimming ability, the fish tended to move to a corner of the recovery tank and remain quiet for some period after the initial recovery. This behavior made it difficult to determine the time required for full recovery. Therefore, the recovery times shown for metomidate are conservative. Recovering fish were darker than fully recovered fish swimming actively in the tank and fish not exposed to the drug. These behavioral differences may be related to the hypnotic effect of metomidate, which induces sleep rather than general anesthesia (Janssen et al. 1975). The prolonged after-effects of the drug were evident at all concentrations tested and were dramatically different from the rapid recovery seen in fish exposed to benzocaine and quinaldine derivatives. This characteristic of metomidate should be considered when recovery time is critical, such as when fish are returned to a natural environment after anesthesia. Gilderhus and Marking (1987) excluded metomidate and etomidate from further research and as potential candidates for registration because of the extended recovery time required. However, because previous work (Davis et al. 1982; Limsuwan et al.

Table 6. *Effects of metomidate concentration and water temperature on time to anesthesia and recovery of striped bass* (n = 5). Shaded area *defines the recommended concentration for that water temperature. Criteria: anesthesia within or close to 3 min and recovery within 10 min following a 15-min exposure.*

Water temperature (° C)	Concentration (mg/L)	Induction time (min) to anesthesia ($\bar{x}$ ± SD)	Recovery time (min) to normal swimming ($\bar{x}$ ± SD)
13	0.5	[a]	2.97 ± 0.25
	2.5	4.87 ± 0.17	9.03 ± 0.98
	5.0	2.94 ± 0.48	10.64 ± 1.41
	7.5	2.03 ± 0.46	9.35 ± 0.93
	10.0	1.28 ± 0.22	10.72 ± 1.10
	15.0	1.03 ± 0.15	13.66 ± 0.38
	20.0	1.16 ± 0.20	48.51 ± 5.49
18	0.5	[a]	2.65 ± 6.16
	2.5	10.83 ± 1.22	5.82 ± 0.53
	5.0	3.24 ± 0.29	12.98 ± 2.76
	7.5	1.64 ± 0.40	14.35 ± 2.69
	10.0	2.23 ± 0.46	11.42 ± 1.44
	15.0	1.24 ± 0.19	12.47 ± 1.28
	20.0	1.16 ± 0.11	15.93 ± 0.38
23	0.5	[a]	[a]
	2.5	[a]	3.18 ± 0.66
	5.0	5.82 ± 0.91	8.47 ± 0.61
	7.5	2.60 ± 0.39	11.82 ± 1.51
	10.0	1.64 ± 0.22	10.17 ± 0.69
	15.0	1.26 ± 0.12	11.02 ± 1.84
	20.0	1.23 ± 0.14	9.70 ± 1.58

[a] Fish were not anesthetized in 15 min.

1983) indicated that etomidate and metomidate caused less physiological stress to fish (as evidenced by blood characteristics), further experimentation on these drugs is warranted. A less stressful drug would be invaluable for the culture of fish such as the striped bass and its hybrids, red drum, and several other species known to succumb to handling and transportation stress (Tomasso et al. 1980; Tomasso and Carmichael 1988; Davis and Parker 1990). Metomidate is an experimental drug and would require FDA registration before being routinely available for use in fish culture.

While all five anesthetics were found effective for striped bass under these test conditions, anesthetic potency may be influenced by such factors as size of fish, temperature, water pH and hardness, length of exposure, and health of the fish. The information supplied in this report should be used as a guide to anesthetic usage with striped bass. Pretesting should be conducted with a small number of fish before the drugs are used on valuable stocks or large quantities of fish.

Acknowledgment

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